

IN THE BATHROOM

1. **Check your toilet for leaks.**
Put a few drops of food coloring in your toilet tank. If, without flushing, the coloring begins to appear in the bowl, you have a leak that may be wasting more than 100 gallons of water per day.
2. **Stop using your toilet as an ashtray or wastebasket.**
Every cigarette butt or tissue you flush away also flushes away five to seven gallons of water.
3. **Use a Toilet Tank Bank.**
Tank Bank is the easiest device to use to save water. Fill it to top, snap to close and hang in the toilet tank. It saves up to 0.8 gallons with every flush.
4. **Take shorter showers.**
A typical shower uses five to ten gallons of water per minutes. Limit your showers to the time it takes to soap up, wash down and rinse off. Shower Coach will help you change shower habits from long to short showers.
5. **Install water saving showerheads and flow restrictors.**
You can save up to 30% of water. They are easy to install, and your showers will be refreshing and enjoyable.
6. **Take baths.**
A partially filled tub uses less water than all but the shortest shower.

7. Turn off the water while brushing your teeth.

Before brushing, wet your brush and fill glass for rinsing your mouth.

8. Turn off the water while shaving.

Fill the bottom of the sink with a few inches of warm water in which to rinse your razor.



KITCHEN and LAUNDRY

9. Check faucets and pipes for leaks.

Even a small drip can waste 50 or more gallons of water a day.

10. Use your automatic dishwasher for full loads.

Every time you run your dishwasher, you use about 25 gallons of water.

11. Use your washing machine only with full loads.

Your automatic washer uses 30 to 35 gallons a cycle.

12. Don't let the faucet run while you clean the vegetables.

Rinse the vegetables instead in a bowl or sink full of clean water.

13. Keep a bottle of drinking water in the refrigerator.

This puts a stop to the wasteful practice of running tap water to cool it for drinking.

14. If you wash dishes by hand, don't leave the water running for rinsing.

If you have two sinks, fill one with rinse water. If you have only one sink, first gather all your washed dishes in a dish rack, then rinse them quickly with a spray device or pan of water.

15. Check faucets and pipes for leaks.

Leaks waste water 24 hours a day, seven days a week.

OUTDOORS

16. Water your lawn only when it needs it.

Step on the grass. If it springs back when you move your foot, it doesn't need water.

17. Deep-soak your lawn.

Water your lawn long enough for water to seep down to the roots where it is needed. A light sprinkling that sits on the surface will simply evaporate and be wasted.

18. Water during the cool parts of the day.

Early morning is better than dusk since it helps prevent the growth of fungus.

19. Use a self-closing nozzle on your hose.

Chapter 8.60 of EMID Municipal Code

WATER CONSERVATION AND RATIONING

8.60.010 Definitions.

As used in this chapter:

- A. "District board" means the board of directors of the Estero municipal improvement district.
- B. "District" means the Estero municipal improvement district.
- C. "District president" means the president of the board of directors of the Estero municipal improvement district.
- D. "District manager" means the district manager of the Estero municipal improvement district.
- E. "District engineer" means the district engineer of the Estero municipal improvement district.
- F. "District counsel" means the district counsel of the Estero municipal improvement district.
- G. "District secretary" means the district secretary of the Estero Municipal improvement district.
- H. "Finance director" means the finance director of the Estero municipal improvement district.
- I. "User" and "customer" mean any person, firm, partnership, association, corporation, company, organization or governmental entity taking water from or using water supplied by the Estero municipal improvement district.
- J. "Unit of water" is one hundred cubic feet of water.
- K. "Water" means water supplied by the Estero municipal improvement district.
- L. "Irrigation" means the watering of grass, lawn, groundcover, shrubbery, annual flowers/plantings, open ground, gardens, trees or other vegetation.
- M. "Water emergency" means any condition related to the district's available water supply which limits its ability to supply a normal amount of water to district customers. (Ord. 116 (part), 1992)

8.60.020 Declaration of water emergency.

In accordance with the provisions of Chapter 3 of the California Water Code, the district board may declare a water shortage emergency condition to prevail and therefore a need to implement mandatory water conservation and/or water rationing which shall remain in effect until the district board determines that the state of water emergency no longer exists. (Ord. 116 (part), 1992)

8.60.030 Mandatory water conservation and rationing policy.

During a state of water emergency, it is the policy of the district to prohibit or restrict certain uses of water which is obtained from the district water supply and to prescribe penalties for violations. (Ord. 116 (part), 1992)

8.60.040 Prohibition of nonessential uses during state of water shortage emergency.

The provisions of this chapter shall apply to all users of water obtained from the district. Notwithstanding other provisions of the Foster City Municipal and Estero Municipal Improvement District Codes inconsistent with this chapter, the provisions of this chapter shall remain in effect

until such time as the district board declares the water shortage emergency over. (Ord. 116 (part), 1992)

8.60.050 Nonessential uses/water conservation.

Upon the district board declaring a water shortage emergency condition to prevail and declaring that water conservation measures are required, it shall be unlawful to use water obtained from the district water supply in the following ways, with the following results or during the following times or conditions:

- A. Washing cars, boats, trailers or other vehicles with a hose that does not have an automatic shut-off device;
- B. Watering grass, lawn, groundcover, shrubbery, annual flowers/plantings, open ground, gardens, trees or other vegetation in a manner that results in runoff into sidewalks, gutters and streets or during periods of precipitation, or to an extent which allows excess water to run to waste;
- C. Watering grass, lawn, groundcover, shrubbery, annual flowers/plantings, open ground, gardens, trees or other vegetation during the hours of ten a.m. through six p.m. on any day of the week;
- D. Allowing or failing to attend to the escape of water through leaks, breaks or malfunction within the water user's plumbing or distribution system for any period of time within which such leak, break or malfunction should reasonably have been discovered and corrected. It shall be presumed that a period of twenty-four hours after the water user discovers or is notified of such break, leak or malfunction is a reasonable time within which to correct such condition or to make arrangement for correction;
- E. Cleaning buildings, structures, walkways, sidewalks, driveways, patios, tennis courts, parking lots or other hard-surfaced areas without prior approval of the water appeals board;
- F. Operating, cleaning or flushing any ornamental fountain or body of water unless there are extenuating circumstances as determined by the appeals board;
- G. Operating a car wash unless water for such use is recycled;
- H. Taking or using water from any fire hydrant unless specifically authorized by permit from the appeals board, except by legally constituted fire protection agencies for fire suppression purposes;
- I. Filling any swimming pool or spa unless there are extenuating circumstances as determined by the appeals board;
- J. Serving water in restaurants except upon request by the customer;
- K. Flushing fire hydrants and water mains unless there is an emergency as determined by the District Engineer;
- L. Running water or washing with water that results in flooding or runoff in or on sidewalks, gutters and streets;
- M. Excess watering of new planting or replanting of any water-dependent landscaping including, but not limited to, any replacement, additional or new grass, lawn, groundcover, shrubbery, annual flowers/plantings, trees, gardens or other vegetation until such time as the district board has determined that the water shortage emergency is over. The planting and replanting should be done in a manner which minimizes the amount of water required;
- N. Using water for consolidation of backfill or dust control;
- O. Any other use of water which is determined to be wasteful as determined by the district engineer. (Ord. 116 (part), 1992)

8.60.060 Nonessential uses/water rationing.

Upon the district board declaring a water shortage emergency condition to prevail and declaring that water rationing measures are required, it shall be unlawful to use water obtained from the district water supply in the following ways, with the following results or during the following times or conditions:

- A. Using water in excess of the following allocations:

1. Residential customers: as specified by resolution of the district board,
2. Industrial customers: as specified by resolution of the district board,
3. Commercial, institutional and governmental customers: as specified by resolution of the district board,
4. Irrigation and outside water usage customers: as specified by resolution of the district board;
- B. Washing cars, boats, trailers or other vehicles with a hose unless the hose has a positive water shut-off device;
- C. Watering grass, lawn, groundcover, shrubbery, annual flowers/plantings, open ground, gardens, trees or other vegetation in a manner that results in runoff into sidewalks, gutters and streets or during periods of precipitation, or to an extent which allows excess water to run to waste;
- D. Watering grass, lawn, groundcover, shrubbery, annual flowers/plantings, open ground, gardens, trees or other vegetation during the hours of ten a.m. through six p.m. on any day of the week;
- E. Allowing or failing to attend to the escape of water through leaks, breaks or malfunction within the water user's plumbing or distribution system for any period of time within which such break, leak or malfunction should reasonably have been discovered and corrected. It shall be presumed that a period of twenty-four hours after the water user discovers or is notified of such break, leak or malfunction is a reasonable time within which to correct such condition or to make arrangement for correction;
- F. Cleaning buildings, structures, walkways, sidewalks, driveways, patios, tennis courts, parking lots or other hard-surfaced areas without prior approval of the water appeals board;
- G. Operating, cleaning, flushing, filling or refilling of any ornamental fountain or body of water, unless there are extenuating circumstances as determined by the appeals board;
- H. Operating a car wash unless water for such use is recycled;
- I. Taking or using water from any fire hydrant unless specifically authorized by permit from the appeals board, except by legally constituted fire protection agencies for fire suppression purposes;
- J. Draining and then filling or refilling of any swimming pool or spa unless there are extenuating circumstances as determined by the appeals board;
- K. Serving water in restaurants except upon request by the customer;
- L. Flushing fire hydrants and water mains unless there is an emergency as determined by the district engineer;
- M. Running water or washing with water that results in flooding or runoff in or on sidewalks, gutters and streets;
- N. Excess watering of new planting or replanting of plant material of any type, including but not limited to, any replacement, additional or new grass, lawn, groundcover, shrubbery, annual flowers/plantings, trees, gardens or other vegetation until such time as the district board has determined that the water shortage emergency is over. Planting and replanting should be done in a manner which minimizes the amount of water required;
- O. Using water for consolidation of backfill or dust control;
- P. Any other use of water which is determined to be wasteful as determined by the district engineer. (Ord. 116 (part), 1992)

8.60.070 Authority to enforce/penalties.

All peace officers of the city of Foster City and public officers and employees duly authorized by the district manager shall enforce this chapter pursuant to Chapter 5C, Title 3, Part 2 of the Penal Code (Section 853.5 et seq). This authority is based on Section 836.5 of the Penal Code. In the performance of their duties the above referred to peace officers and officers and employees have the authority to issue citations to appear in court for violations of this chapter.

A. Violation of any provisions of this chapter, including the use of water in excess of the allotments set forth in subsection A of section 8.60.060 is subject to penalties as provided for in Section 356 of the California Water Code. Additionally, the district may require installation of a flow-restricting device on the water service line.

- B. Charges for installation of flow-restricting devices and restoration of service shall be specified by resolution of the district board.
- C. Continued water consumption in excess of the allocation may result in discontinuance of water service by the district.
- D. A charge of one hundred dollars shall be paid prior to reactivating water service.
- E. Except as specifically stated elsewhere, any violation of the provisions of this chapter shall be punishable as an infraction, the penalty for which shall be as follows:
 - 1. A fine not exceeding one hundred dollars for a first violation;
 - 2. A fine not exceeding two hundred dollars for a second violation within one year;
 - 3. A fine not exceeding five hundred dollars for each additional violation within one year. (Ord. 116 (part), 1992)

8.60.080 Disconnection.

Any user in violation of the provisions of Section 8.60.050 or 8.60.060 who fails to take corrective action after the first notification of the violation shall be subject to disconnection of water service. Upon disconnection of water service, a written notice shall be served upon the violator, or conspicuously posted at the entrance to the location where the violation has occurred and which shall state the time, place and general description of the violation and the method by which reconnection may be accomplished. (Ord. 116 (part), 1992)

8.60.090 Appeals board, appeals and exceptions.

- A. An appeals board shall be established that is comprised of the district manager, finance director and the district president or their designees.
- B. A written appeal for an exception to use water contrary to the provisions of Sections 8.60.050 and/or 8.60.060 or for an adjustment in an allocation of water may be made to the appeals board. Such appeal shall clearly state the basis for the appeal, the cause or reason why special consideration should be given by the appeals board, any corrective measures that must and will be taken and when they will be completed, the specific relief sought and any other pertinent information. The appeals board may:
 - 1. Allow the planting of materials selected from an approved list of drought-tolerant plant materials obtained from the district and which are planted in low water use landscape designs and which employ low water use irrigation systems. The written appeal shall include a complete description of the planting request including the exact number and type of materials to be planted, how low water use landscape designs and irrigation systems will be used, and any other descriptive information likely to be of assistance to the appeals board in rendering a decision; or
 - 2. Allow the use of water otherwise restricted or prohibited; or
 - 3. Adjust an allocation of water if it finds that:
 - a. Failure to do so would cause an emergency condition adversely affecting the health, sanitation, fire protection or safety of the user or the public, and/or;
 - b. The user has adopted all practicable water-conservation measures, and/or;
 - c. Failure to do so would cause unnecessary and undue hardship to the customer or the public.
- C. Any user who believes that an activity or condition which resulted in the disconnection of water service pursuant to this chapter did not constitute a violation of this chapter may appeal the disconnection in writing to the appeals board. If the appeals board finds that the activity or conduct did not constitute a violation of this chapter or was reasonable or unavoidable or for another reason should not be penalized, the user shall be reconnected to the water supply system and the reconnection charge shall be refunded. (Ord. 116 (part), 1992)

8.60.100 Reconnection.

A. Where water service is disconnected as authorized in Section 8.60.080, it shall be immediately reconnected upon correction of the condition or activity and payment of a reconnection charge of one hundred dollars.

B. Those water users that are serviced by a master meter for both domestic supply and irrigation and who are disconnected for violating any of the provisions contained within this chapter, shall, upon receiving written notice from the district engineer, do and be subject to the following:

1. Post a cash bond in an amount determined by the district engineer to install a separate water service line and meter for the property owner's irrigation system within sixty days of the water disconnection.

2. If the owner fails to install the new water service line and meter within the sixty days, the district shall utilize the cash bond to pay for installation costs associated with installing the water service line and meter. Any funds remaining after the installation of the water service line and meter shall be returned to the customer. Additional funds may be collected from the user by the district if the original amount was insufficient to complete installation of the service line and meter. (Ord. 116 (part), 1992)

8.60.110 New connections.

Water service connections to accommodate new developments, new construction or new users shall be granted only if water saving fixtures or devices are incorporated into the users plumbing and landscape irrigation system. For new developments in which water dependent landscaping is required as a use permit condition, the district shall require a cash bond or other form of security subject to approval of the district counsel from the developer in an amount equal to the estimated cost of landscaping plus ten percent. Cash deposits will be placed in an account in which the interest shall accrue to the developer. (Ord. 116 (part), 1992)

8.60.120 Excess water use charge.

A. An excess use charge as determined by resolution of the district board may be levied for water used in excess of the allocations specified by resolution of the district board.

B. Additional charges to all users may be imposed to compensate for a loss of revenue to the district or to pay for any additional cost to the district associated with the purchase of more water. (Ord. 116 (part), 1992)

8.60.130 Waiver of excess water use charge.

Written application for a waiver of an excess water use charge may be made to the appeals board. Such application shall contain all of the information required in Section 8.60.090 of this chapter.

A. The appeals board may waive a specific excess water use charge if it finds, based upon information and/or facts presented, that sufficient justification is present to allow such a waiver.

B. A waiver may be granted for one or more of the following reasons:

1. Water used in excess of the allocation was for the protection of health and/or sanitation or for the protection of property in the case of fire.

2. Water used in excess of allocation was the result of a condition unknown to the user which has subsequently been corrected to the satisfaction of the appeals board.

C. A waiver shall not be granted unless the user has adopted and has demonstrated all practicable water conservation or rationing measures, nor shall a waiver be granted on the basis of economic hardship. (Ord. 116 (part), 1992)

City of Foster City

PLANTING AND IRRIGATION

GUIDELINES



FOSTER CITY PLANTING AND IRRIGATION GUIDELINES

I. INTRODUCTION

A. BACKGROUND

Efficient use of water in California is a key issue as the State's population and demand for water continues to grow. The recent droughts of 1976-77, 1987-90 and the possibility of future droughts put tremendous demand on this precious limited resource. This has forced many water agencies throughout the State to undertake strict conservation measures and, in many cases, including rationing.

Within Foster City a major portion of water consumption in residential and commercial sites is used to water outdoor landscaping. With this in mind, the Estero Municipal Improvement District has developed the following water conserving planting and irrigation guidelines. The purpose of the landscape guidelines is to assist residents and businesses in reducing landscape water consumption.

These landscaping planting and irrigation guidelines are designed to aid developers, property owners and homeowners in selecting appropriate plant materials and in installing irrigation systems to create water conserving landscapes which are appropriate to local soil and weather conditions.

The guidelines have seven sections: Section I, *Introduction*; Section II, *Landscape Planting and Irrigation Guidelines for New and Existing Landscapes*; Section III, *Miscellaneous Water Conservation Measures*; Section IV, *Low-Water Using (Drought Tolerant) Plant List*; Section V, *Maintenance of New and Existing Landscapes for Water Conservation*; Section VI, *Glossary of Terminology*; and Section VII, *Sources and References*.

B. OVERVIEW OF FOSTER CITY'S ENVIRONMENT

Climate

Foster City's climate is heavily influenced by the ocean and San Francisco Bay, creating cool summers with frequent fog or wind, and cool, wet winters. The temperatures are mild, typically ranging from the 60°s to 80°s in the summer to the high 30°s to 50°s in the winter. Foster City seldom suffers serious or heavy frosts, consequently many subtropical plants can thrive here. However, heat-loving plants may find the summers a little too cool to bloom. Wind from the bay is common throughout the City, with the heaviest salt-laden winds occurring along the bay frontage. Generally, unless plants grown in these areas are sheltered from the salty winds, only those with wind and salt tolerance will be able to survive. There are a large variety of low-water using plants ideally suited to the climate within Foster City. A low-water using landscape need not be dull or unattractive. In fact, many water conserving plants offer year-round flowers, fruit, and showy foliage. Choosing the proper plants for the climatic conditions at a specific site is the key to a successful, healthy, and beautiful landscape.

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Soils

The majority of the soils within Foster City are fill material obtained from Bay dredging. This, coupled with the fact that development progressed over a number of years, has resulted in a variety of soil types throughout the City. These variations in soil type can have a major impact on plant growth and irrigation rates. Much of the dredged soils contain high quantities of dissolved salts and minerals which, if high enough in concentration, require periodic leaching. Some soils may have very poor permeability which requires careful water application to avoid runoff. Poor soil conditions need to be identified in order to apply proper corrective measures for healthy plant growth.

Even within a given site, there may be soil and climatic variations or "microclimates" that require special attention in the design process. All of these weather and soil conditions must be considered when selecting plant materials and designing an irrigation system for a site. These guidelines provide a framework for developing a low-water using planting program for use in Foster City landscapes. It is highly recommended that a competent professional be consulted during the design process to ensure that all aspects of the site's unique properties are considered in the final landscape plan.

C. APPLICABILITY

These guidelines are applicable to the following new and existing landscape installations:

1. Single Family Homes
2. Model Homes
3. Townhomes, Condominiums, Apartments
4. Industrial Sites
5. Office Sites
6. Retail Sites
7. Institutional Sites, Churches
8. Public Works Projects

II. LANDSCAPE PLANTING AND IRRIGATION GUIDELINES FOR NEW AND EXISTING LANDSCAPES

These planting and irrigation guidelines are intended to aid in designing and selecting low-water using plant materials and water conserving irrigation systems for both new and existing landscapes.

A. LANDSCAPE PLANTING

1. Replacing Existing Landscaping
 - a. If redesigning your entire landscape at one time is not feasible, begin by replacing the "thirsty" plants with low-water using plants. You can stagger the replacement of existing plants over several months. Prioritize replacing areas of landscaping with the highest visibility and/or use first, such as front yard or entry areas. If you choose to replace a limited area instead of the entire existing landscaping, you will need to modify your existing irrigation system to properly apply

water to your new landscaping. If the section of landscaping you are replacing is fairly large, it is highly recommended that you replace the existing irrigation system instead of upgrading it. *Replacement of the irrigation system allows it to be designed properly, ensuring correct and efficient water application. (See the following section on irrigation systems.)*

- b. Maintain as much existing low-water using vegetation as possible when upgrading your landscaping. Try to incorporate these plant materials into your overall design instead of replacing them. *Established vegetation will use much less water than newly planted nursery stock.*
- c. To save even more water in the future, turfgrass areas can be replaced with low-water using ground covers.

2. Plant Selection

- a. Select low-water using plant materials that are suitable to Foster City's climate and cultural conditions. *(See the low-water using list of plants in Section IV for examples.)*
- b. For sites within the City that experience heavy salt-laden winds, choose plants suitable to those conditions. The low-water using plant list also denotes which plants can survive under these conditions. *Plants not tolerant of salty winds will survive only if they are grown in a sheltered location.*
- c. Some areas of Foster City have high saline soils. Saline soil conditions are detrimental to the health of plants. Choose plants suitable to these conditions. *(See the low-water using plant list, as these plants have been specifically chosen for Foster City's soil types and climate conditions.) To determine if you have this type of soil problem, see Item 6 below on obtaining a soils test.*

3. Turf Grass and Annuals

- a. The use of turf grasses and annuals (such as petunias, marigolds, etc.) should be limited in the landscape. Annuals should be treated as turf because of their high water use. The combined planting areas of annuals and turf should not exceed 25 percent of the total landscaped areas. *Limiting turf areas saves water. More than half of a typical household's water use goes to irrigating lawn areas. Limiting turf and annuals to 25 percent of planted areas can save a considerable amount of water and still provide an attractive landscape.*
- b. Turf should not be used in narrow strip areas such as: median strips or islands in parking lots, areas less than eight feet wide, and areas

between curbs and sidewalk. *Irrigating small narrow areas of turf results in high rates of runoff. Irrigating larger lawn areas will allow water a greater chance of soaking into the soil or running off into the surrounding landscaping.*

- c. Turf should be a low-water using variety of grass. Use "tall fescue" or "hard fescue" variety instead of the typical "bluegrass" mixes. *Low-water using grasses use 10 to 20 percent less water than "bluegrass" mixes.*
- d. Avoid planting turf on slopes exceeding a 4:1 ration (see glossary for definition). *Planting turf on steeper slopes encourages more runoff and is difficult to mow.*

4. Grouping Plant Materials

Plant materials should be planted in groups based upon their water needs. For example, turf areas with annuals should be located in one area, while low-water using trees or shrubs should be planted in another area. *The grouping of plants with like water requirements allows you to design the irrigation system to water these plant groups separately. This creates an efficient irrigation system and minimizes water waste.*

5. Planting Time

Landscape plant materials can be planted any time of the year. However, the best time to begin planting your landscape is in the fall. *Planting in the cooler humid and rainy fall weather promotes root growth and allows plants to become established before the warm summers. Established plants will require less water in summer.*

6. Soils and Soil Amendments

- a. The soil at your site should be tested for agricultural suitability and fertility. This type of soils test will list the nutrients necessary to add to the soil to encourage healthy plant growth. It will also tell you if the soil is highly saline and what can be done to correct the problem. *Saline soils can stunt a plant's growth and may eventually kill it. Plants may not show signs of salt damage for some time, at which point it may have stunted the plant permanently. Soils tests are relatively inexpensive and a good insurance measure when considering the time and money you invest in your new landscaping.*
- b. Organic amendments should be added to all planting areas. Rototill a two-inch layer of organic amendments, such as nitrogen stabilized redwood, thoroughly into the top six to eight inches of soil (or as recommended by the soil's report). *Organic matter will improve the soil's ability to absorb and retain water and nutrients.*

c. **Leaching**

Soils with high salt concentrations will require periodic leaching to prevent damage to plants. Follow the recommendations of the soils report on how much or how often leaching must be done. *Leaching is heavily watering the soil to flush the salts down below the plant's root zone.*

7. **Backfill Planting Mix**

Mix one part organic amendment to three parts existing soil (or as recommended by the soils report). Use this soil mix to fill the planting holes when you place your trees or shrubs in the ground. *This will help to retain soil moisture.*

8. **Mulching**

A two-inch layer of bark mulch should be added over all non-turf areas in your landscape. *This mulch layer will moderate soil temperatures, reduce water loss through evaporation, and discourage weed growth.*

Fertilizing

Fertilizer should be applied on a regular basis to encourage healthy plant growth. Be careful not to over fertilize. *Over fertilizing can cause excessive plant growth and increased water demand. It can also burn and damage a plant's roots, making it more susceptible to water stress and disease. (See the section on maintenance for information on proper fertilization procedures.)*

B. IRRIGATION SYSTEMS

1. **Irrigation System Design**

Irrigation systems should be designed by a licensed landscape architect, certified irrigation designer, or other competent professional. *A properly designed irrigation system can provide water conserving benefits.*

2. **Automatic Irrigation Controller**

a. All new irrigation systems should include an automatic controller. Existing irrigation systems with manual controls should be retrofitted with automatic control valves and an automatic controller. The controller should be capable of the following:

1. Multiple start capacity
2. Flexible calendar program
3. Capable of dual or multiple programming
4. Rain switch to temporarily bypass program in times of rain

5. Battery back-up to retain program in power outages

Adding an automatic controller allows for precise water application and can provide considerable water savings. These features allow for different summer and winter irrigation schedules.

- b. The controller should operate the irrigation system between the hours of 6:00 p.m. and 10:00 a.m. *Operating the system during these hours when the sun is down or of less intensity minimizes water loss due to evaporation.*
- c. The controller should be programmed to operate the irrigation system so as to minimize water runoff (see Item 5 below on programming controller for soils with poor permeability). *This will require you to observe how long your planting areas need to be watered before runoff occurs and note how long an area can go before the plants require watering again. Once these facts are known, you can program the controller to provide only as much water as plants need.*

3. Moisture Sensing Devices

Moisture sensing devices can be added to the irrigation system for optimum water savings. Choose sensors that are compatible with your irrigation controller. *Moisture sensing devices detect the amount of water in the soil at the plant's root zone. They convey this information to the controller, which will then irrigate the plants only when they need water. This eliminates over and under watering. This system, once installed and set up, provides a nearly hassle free irrigation schedule that requires little or no seasonal program modifications.*

4. Separate Planting Groups Into Separate Irrigation Circuits

- a. Irrigation heads should be grouped in a valve circuit which irrigates groups of plants with like water needs. *By grouping plants with similar water needs into one irrigation circuit, the group can be irrigated separately from other planting groups and areas which may require different amounts of water. For example, turf areas require more water than ground cover areas and should be on a separate valve circuit.*
- b. Sun and shade areas should be grouped into separate irrigation valve circuits, as should sloped and flat ground areas. *Sun and shade planting areas have different water use requirements. Sloped areas require shorter watering cycles to avoid water runoff over the ground surface.*

- c. **Trees in all planting areas should be irrigated with bubbler or drip emitters in addition to overhead spray which is used to irrigate turf, shrubs, and ground cover. *Trees require periodic deep watering to encourage healthy growth. This type of watering also encourages trees to develop deep roots which can tap into ground water table, thus, allowing trees to become self sufficient. Bubbler or drip emitters provide water at a slow rate allowing it to soak deep into the soil without runoff. Trees which do not receive deep root watering will be more prone to water stress and diseases during times of drought.***
- d. **Shrubs should be irrigated with bubbler or drip emitter where appropriate. *This method eliminates overspray and uses less water than conventional overhead spray irrigation.***

5. Precipitation Rates

- a. **All sprinkler heads within each irrigation circuit should have matched precipitation rates. Existing irrigation systems with older sprinkler heads can easily be retrofitted to this type of irrigation system. *Matched precipitation rate sprinkler heads provide uniform water coverage ensuring that all planting areas receive equal amounts of water.***
- b. **Precipitation rate of the sprinklers should match with the permeability rate (water intake) of the soil to prevent runoff. *Water should not be applied faster than a soil can absorb it.***
- c. **Soils with poor permeability (such as heavy clay soils) are more prone to runoff. The irrigation controller should be programmed to operate the valve circuits in multiple cycles of shorter durations. A minimum of one hour should pass between repeat cycles to allow water to penetrate into the soil. *No runoff should occur with each repeat cycle.***
- d. **No overhead irrigation system should be used on slopes exceeding 2:1 (see glossary). Low flow bubblers and/or emitters should be used, as they have a low gallon per minute (gpm) output. *Overhead sprinklers on steep slopes will cause water runoff.***

6. Sprinkler Head Spacing

- a. **Spacing should be head to head coverage with a maximum spacing of 50 percent of "throw diameter" (see glossary). *Proper head spacing ensures optimum water coverage. Consult the literature provided by the sprinkler head manufacturer for more information.***
- b. **In windy areas use closer spacing, such as 45 percent of "throw diameter." The shorter distance between heads (45 percent of "throw diameter") should be perpendicular to the wind, with the longer spacing**

(50 percent of "throw diameter") between the rows of heads parallel to the wind. Use low angle spray heads to combat the wind and prevent misting (see item 10 below).

- c. Triangular head spacing should be used where possible. *Triangular spacing provides more even water coverage than square spacing.*
- d. Square head spacing should be used in rectangular planting areas that are adjacent to paving or non-irrigated areas to minimize overspray. *Square spacing generally has less overspray than triangular space; however, coverage is not as even as in triangular spacing.*

7. Low-Head Runoff

Sprinkler heads installed at lower elevations in the valve circuit should have check valves installed to limit low-head runoff. *This occurs after the irrigation system has been stopped. Water in the irrigation pipes will drain out through the lowest heads in the system creating water, thus creating water waste.*

8. Turf Irrigation Heads

Four-inch pop-up heads should be used in new and existing lawn areas. *This prevents taller turf from blocking coverage and causing runoff.*

9. Drip and Bubbler Equipment

- a. All drip valve circuits should include a pressure regulator, filter and pressure gauge.
- b. Drip emitters should be placed within the drip line of the tree or shrub canopy. *This allows the water to soak into the soil where most of the plant's roots are located.*
- c. All bubbler valve circuits should use bubbler heads that put out a constant flow at 20 to 90 psi pressure or include a pressure regulating valve, riser or head. *Pressure regulators maintain a constant pressure in the irrigation circuit ensuring that the emitter, bubbler or head flow at a constant and even rate. This allows for more precise control of how much water is applied to the plant.*

10. Misting

- a. Misting sprinkler heads should be corrected. Correct by turning the heads adjustment screw until misting stops. *Misting occurs when the sprinkler head produces a mist or fog of water. This mist will drift away from the areas being irrigated. This creates considerable water waste.*

- b. Fluctuating or high water pressure at the irrigation systems P.O.C. (point of connection to the municipal water service) can cause properly adjusted sprinklers to begin misting or fogging. Where this condition exists, a pressure regulating device should be installed at the P.O.C. of the irrigation system.

11. System Adjustment

All sprinkler heads should be adjusted to optimize coverage and eliminate overspray. *Overspray occurs when the sprinkler heads spray beyond a planting area and onto paving or other non-irrigated surface.*

III. MISCELLANEOUS WATER CONSERVATION MEASURES

A. DECKING

Wood decking is a good alternative to a concrete patio. It has a soft and pleasing appearance and allows rain water to percolate into the soil during winter. Rain water can help replenish the water table, thereby reducing nearby trees' dependence on summer irrigation.

B. PERMEABLE PAVING SURFACES

Permeable paving is one which allows water to penetrate the soil below and reach plant roots. Some permeable paving can be used in place of concrete paths, walkways, and even driveways. Examples are listed below:

- a. Decomposed granite aggregate or "DG". This material is ideally suited for footpaths in the garden. It is made up of crushed granite and comes in several shades of gray and brown. To construct a pathway, headerboard is first installed to define and align the edges of the path, then the "DG" is installed and compacted. The final product is a hard, durable surface which rain and irrigation water can soak through.
- b. Bark mulch can be used to provide a walking surface in the landscape. There are many types of bark products available on the market, each with different colors and textures. It is the most economical and simplest form of permeable paving, and it lends an informal and natural character to landscape design.
- c. Brick can be used as walkways or patios, creating a formal rustic look. Many colors and types of brick can be used. The simplest way to install brick is to place it on a level one-inch layer of compacted sand with sand swept between the joints. Headerboards can be used along the edges to hold them in.
- d. Turf block is an open plastic or concrete brick like block which, if installed properly, can take vehicular traffic. Large areas of turf block can be installed to serve as driveways or parking areas. Each block has an opening or core allowing turf and ground cover to grow.
- e. Check with your local nursery which should have additional ideas or information for you to consider.

C. FOUNTAINS AND PONDS

1. Water bodies in the landscape should be considered the same as turf areas. Water surfaces combined with turf and annuals should not exceed 25 percent of the total planted area.

2. Water features which spray water into the air are prohibited. *These features cause considerable water waste because of the evaporation caused by wind and sun.*

D. POOL AND SPA COVERS

Provide pool and spa covers to minimize water evaporation and heat loss.

E. SOIL POLYMERS

Soil polymers may be incorporated into the soil to improve water and nutrient retention. Avoid using polymers in soils that require periodic leaching. Apply per manufacturer's recommendations.

IV. LOW-WATER USING (DROUGHT TOLERANT) PLANT LIST

A. The following plant list has been adapted from the East Bay Municipal Utility District's book, Water-Conserving Plants & Landscapes for the Bay Area. Included are nine categories of information organized in a matrix. Below is a description of each category:

1. *Deciduous*: A plant which loses its leaves during winter.
2. *Evergreen*: A plant which has leaves all year round. Several plants are listed as both evergreen and deciduous. This means that the plant may become partially deciduous depending on how cold it becomes.
3. *Flowers*: A plant in this category will have a display of flowers during the growing season.
4. *Fall Color*: A plant which will produce a leaf display of color in the fall.
5. *Full Sun*: A plant that requires full sun exposure during the day for optimum growth. Growing such a plant in shady conditions can result in poor growth with little or no flowering.
6. *Partial Shade*: A type of plant that tolerates some sun but prefers shade during the day. Note: Many of these plants can take both conditions.
7. *Well-Drained Soil*: A plant that requires well-drained soil. Planting such a plant in poorly drained soil can result in poor growth and disease.
8. *Alkaline Soil*: Plants that can tolerate soils with high pH values (pH 8 to 9) and excessive levels of calcium and magnesium. A number of these plants can also tolerate high sodium levels. Consult with your nursery when selecting plants from this category for tolerance to saline soils. A soils test is highly recommended to determine if your soil has these conditions. Installing plants that are not tolerant of these conditions will result in very poor growth.
9. *Sea Coast Conditions*: Plants in this category are capable of performing well within 1,000 feet of the ocean or bay. Most of these plants can tolerate salt-laden air and winds.

B. When purchasing your plant materials, consult your local nursery about your soil conditions, wind, sun and shade exposures. The nursery employees can provide you with information and plant selections in order to help you make the right choices.

LOW-WATER USING (DROUGHT TOLERANT) PLANT LIST

	Sea Coast Conditions								
	Alkaline Soil								
	Well Drained Soil								
	Partial Shade								
	Full Sun								
	Fall Color								
	Flowers								
	Evergreen								
	Deciduous								
TREES									
Acacia baileyana - Bailey's Acacia		x	x		x				x
Agonis flexouosa - Peppermint Tree		x			x	x		x	x
Alnus cordata - Italian Alder	x				x	x		x	
Callistemon species - Bottle Brush		x	x		x	x	x	x	x
Carpinus betulus "fastigiata" - Upright Betulus Hornbeam	x				x				
Casuarina cunninghamiana - River She-Oak		x			x			x	x
Cedrus atlantica - Atlas Cedar		x			x			x	x
Cerciscan adensis - Eastern Redbud	x		x	x	x				
Crataegus phaenopyrum - Washington Hawthorn	x		x	x	x				
Cupressus glabra - Smooth Arizona Cypress		x			x			x	
Dodonea viscosa - Hopseed Brush		x			x		x	x	x
Eriobotrya deflexa - Bronz Loquat		x	x		x	x	x		
Eriobotrya japonica - Japanese Loquat		x	x		x	x	x	x	
Eucalyptus ficifolia - Red Flowering Gum		x	x		x		x		
Eucalyptus leucoxylon rosea - Pink Flowered Ironbark		x	x		x		x	x	x
Eucalytus microtheca - Coolibah Tree		x	x		x			x	x
Fraxinus oxycarpa raywood - Raywood Ash	x				x				
Fraxinus uhdei - Evergreen Ash		x			x			x	
Fraxinus moraine - Moraine Ash	x			x	x		x		

LOW-WATER USING (DROUGHT TOLERANT) PLANT LIST

	Sea Coast Conditions								
	Alkaline Soil								
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	Partial Shade								
	Full Sun								
	Fall Color								
	Flowers								
	Evergreen								
	Deciduous								
TREES									
Geijera parviflora - Australian Willow		x			x		x		
Ginkgo biloba cultivars - Maidenhair Tee	x			x	x				x
Juglans nigra - Eastern Black Walnut		x		x	x				
Juniperus C. "torulosa" - Hollywood Juniper		x			x				
Koelreuteria bipinnata - Chinese Flame Tree	x	x	x	x	x	x	x	x	x
Koelreuteria paniculata - GoldenRain Tree	x		x		x				
Laurus "saratoga" - Hybrid Laurel		x			x	x		x	x
Ligustrum lucidum - Glossy Privet		x	x		x				
Malus "robinson" - Robinson Crabapple	x		x	x	x				
Melaleuca linarifolia - Flaxleaf Paperback		x	x		x	x			
Melaleuca quinquenervia - Cajeput Tree		x	x		x	x		x	x
Melaleuca styphelioides - Prickly Melaleuca		x	x		x	x			x
Metrosideros excelsus - New Zeland Christmas Tree		x	x		x	x			x
Myoporum Laetum - Myoporum		x	x		x	x		x	x
Olea europea - European Olive		x			x		x		x
Parkinsonia aculeata - Jerusalem Thorn	x		x		x		x		
Pinus eldarica - Eldarica Pine		x			x			x	
Pinus pinea - Italian Stone Pine		x			x				x
Pinus sylvestris - Scot's Pine		x			x	x			x
Pinus thunbergiana - Japanese Black Pine		x			x	x	x		x

LOW-WATER USING (DROUGHT TOLERANT) PLANT LIST

	Sea Coast Conditions								
	Alkaline Soil								
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	Full Sun								
	Fall Color								
	Flowers								
	Evergreen								
	Deciduous								
TREES									
Pittosporum undulatum - Victorian Box		x	x		x	x	x		
Platanus acerifolia - London Plane Tree	x			x	x	x			
Podocarpus gracilior - African Fern Pine		x			x	x	x		
Populus fremontii "nevada" - Nevada Male Cottonwood	x			x	x	x			
Populus nigra "italica" - Lombardy Poplar	x			x	x	x	x	x	x
Prunus cerasifera cultivars - PurpleLeaf Plum	x		x		x		x		
Pyrus kawakamil - Evergreen Pear		x	x		x	x	x		
Pyrus calleryana cultivars - Flowering Pear	x	x	x	x	x			x	
Quercus suber - Cork Oak		x			x	x	x		
Quercus ilex - Holly Oak		x			x		x	x	x
Quercus agrifolia - Coast Live Oak		x			x	x	x		
Robinia ambigua "idahoensis" - Idaho Locust	x		x	x	x		x		
Salix babylonica - Common Willow	x				x	x	x	x	x
Saphora japonica - Chinese Scholar Tree	x		x		x	x			
Schinus molle - California Pepper Tree	x				x			x	x
Sequoia sempervirens - Coast Redwood		x			x	x			x
Tristania laurina - Swamp Myrtle		x	x		x	x			
Tristania conferta - Brisbane Box		x	x		x		x		x

LOW-WATER USING (DROUGHT TOLERANT) PLANT LIST

	Sea Coast Conditions							
	Alkaline Soil							
	Well Drained Soil							
	Partial Shade							
	Full Sun							
	Fall Color							
	Flowers							
	Evergreen							
	Deciduous							
SHRUBS								
Abelia grandiflora - Glossy Abelia		x	x		x	x		
Agapathus africanus - Lily of the Nile		x	x		x	x	x	x
Alyogyne huegelii - Blue Hibiscus		x	x		x		x	x
Arbutus unedo - Strawberry Tree		x	x		x	x		x
Arctostaphylos densiflora "Howard McMinn" - Manzanita		x	x		x	x		x
Baccharis - Coyote Bush		x			x	x	x	x
Ceanothus species - Wild Lilac		x	x		x		x	
Cistus species - Rockrose		x	x		x			x
Coprosma kirka - Dwarf Mirror Plant		x			x	x	x	x
Correa species - Australian Fuschia		x	x		x	x	x	
Cotoneaster lacteus - Red Clusterberry		x	x		x	x		
Cotoneaster congesta "Likiang" - Likiang Cotoneaster		x	x		x			
Echium fastuosum - Pride-of-Madera		x	x		x	x	x	x
Escallonia dwarf species - Escallonia		x	x		x	x		x
Escallonia fradesii - Escallonia		x	x		x	x	x	x
Euryops pectinatus - Golden Shrub Daisy		x	x		x			x
Grevillea rosmarinifolia - Rosemary Grevillea		x			x		x	
Heteromeles arbutifolia - Toyon		x	x			x	x	
Leptospermum laevigatum - Australian Tea Tree		x	x		x	x		x
Myrica californica - Pacific Wax Myrtle		x			x	x		x

LOW-WATER USING (DROUGHT TOLERANT) PLANT LIST

	Sea Coast Conditions							
	Alkaline Soil							
	Well Drained Soil							
	Partial Shade							
	Full Sun							
	Fall Color							
	Flowers							
	Evergreen							
	Deciduous							
SHRUBS								
Myrsine africana - African Box	x			x	x		x	
Nandina Species - Heavenly Bambo	x	x		x	x	x		x
Nerium oleander - Oleander	x	x		x				
Osmanthus fragrans - Sweet Olive	x	x		x	x		x	
Phormium tenax - New Zealand Flax	x	x		x			x	x
Photina fraseri - Fraser Photina	x	x		x	x			
Pinus mugo - Swiss Mountain Pine	x			x	x	x		x
Pittosporum eugenioides - Pittosporum tenuifolium	x			x	x	x		
Plumbago auriculata - Cape Plumbago	x	x		x	x			
Podocarpus macrophylla - Yew Pine	x			x	x			x
Prunus illicifolia - Holly-Leaf Catalina Cherry	x	x		x	x	x		x
Rhapiolepis species - India Hawthorn	x	x		x		x		
Rhus integrifolia - Lemonade Berry	x	x		x	x	x	x	x
Sarcococa ruscifolia - Fragrant Saracococa	x	x			x			
Sollya heterophylla - Australian Bluebell	x	x			x	x		x
Syzygium paniculatum - Australian Brush Cherry	x	x		x	x	x		x
Tetrapanax papyrifera - Rice Paper Plant	x	x		x	x	x	x	x
Viburnum tinus - Laurestinus	x	x		x	x	x	x	
Westringia rosmariniformis - Rosemary Bush Westringia	x	x		x		x		x
Xylosma congestum - Shiny Xylosma	x			x				

LOW-WATER USING (DROUGHT TOLERANT) PLANT LIST

Sea Coast Conditions									
Akaline Soil									
Well Drained Soil									
Partial Shade									
Full Sun									
Fall Color									
Flowers									
Evergreen									
Deciduous									
PERENNIALS									
Acanthus mollis – Bear's Breech	x	x	x			x		x	x
Agapanthus species – Lily-of-the-Nile		x	x		x	x			x
Aloe species – Aloe		x	x		x	x	x		x
Aspidistra elator – Cast Iron Plant		x			x			x	x
Dietes vegata – Fortnight Lily		x	x		x	x		x	x
Diplacus hybrids – Monkey Flower		x	x		x	x			x
Hemerocallis species – Daylilies	x	x	x		x	x		x	x
Iris douglasiana – Douglas Iris		x	x		x	x	x		x
Iris hybrids – Iris	x		x		x	x		x	
Lantana montevidensis – Trailing Lantana		x	x		x				x
Limonium perezii – Sea Lavender		x	x		x	x	x	x	x
Myosostis sylvatica – Forget-Me-Not	x	x	x	x	x	x	x	x	x
Santolina chamaecyparissus – Gray Lavender Cotton		x	x		x		x	x	x
Santolina virens – Green Lavender Cotton		x	x		x		x	x	x
Tulbaghia violacea – Society Garlic		x	x		x	x			x
GROUND COVERS									
Armeria maritime – Sea Thrift		x	x		x		x		x
Baccharis pilularis "twin peaks" – Dwarf Coyote Brush		x			x				x
Ceanothus gloriosus "porrectus" – Mount Vision Ceanothus		x	x		x	x	x		

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Akaline Soil									
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Full Sun									
Fall Color									
Flowers									
Evergreen									
Deciduous									
GROUND COVERS									
Ceanothus hearstiorum - Hearst Ceanothus		x	x		x		x		
Cistus salvifolius - Sageleaf Rockrose		x	x		x				x
Coprosma kirkii - Creeping Coprosma		x			x				x
Festuca o. glauca - Blue Fescue		x			x	x	x	x	x
Gazania Species & Hybrids		x	x		x		x	x	x
Hypericum calycinum - St. John's Wort		x	x		x			x	x
Ice Plant Species		x	x		x	-	x	x	x
Oenothera berlandierii - Mexican Evening Primrose	x		x		x				x
Phyla nodiflora - Lippia (Good Lawn Substitute)	x	x	x		x			x	x
Polygonum capitatum - Pink Knotweed	x	x	x	x	x	x	x		x
Rosemarinus officinalis cultivars - Rosemary		x	x		x		x		x
Scaevola "mauve clusters" - Fan Flower		x	x		x	x	x	x	x
Stachys byzantina - Lamb's Ears		x	x		x	x	x	x	x
Verbena tenuisecta - Moss Verbena		x	x		x				
VINES									
Bougainvillea species - Bougainvillea	x		x		x				x
Campis radicans - Trumpet Creeper	x		x		x				x
Cissus antarctica - Kangaroo Ivy		x			x	x		x	x
Cissus antartica - Kangaroo Ivy		x			x	x		x	x

LOW-WATER USING (DROUGHT TOLERANT) PLANT LIST

	Sea Coast Conditions							
	Akaline Soil							
	Well Drained Soil							
	Partial Shade							
	Full Sun							
	Fall Color							
	Flowers							
	Evergreen							
	Deciduous							
VINES								
Clytostoma callistegioides - Lavender Trumpet Vine		x	x		x	x		
Dicticus buccinatoria - Blood Red Trumpet Vine		x	x		x		x	x
Gelsemium sempervirens - Carolina Jessamine		x	x		x	x		
Hedera helix - English Ivy		x			x	x	x	x
Jasminum polyanthum - Pink Jasmine		x	x		x		x	
Lonicera hildebrandiana - Giant Burmese Honeysuckle		x	x		x			x
Macladyena unguis-cati - Cat's Claw	x	x	x		x			
Parthenocissus tricuspidata - Boston Ivy	x			x	x	x		x
Passiflora caerulea - Passion Vine		x	x			x		x
Rosa banksiae - Lady Banks Rose		x	x		x		x	
Solanum jasminoides - Potatoe Vine	x	x	x		x			
Wisteria species - Wisteria	x		x		x	x		

V. MAINTENANCE OF NEW AND EXISTING LANDSCAPES FOR WATER CONSERVATION

A. PLANTING MAINTENANCE

Developing a regular maintenance program is essential to maintaining a healthy water conserving landscape. A poorly maintained landscape not only looks unattractive but can waste water and spread weeds, pests and diseases to nearby healthy landscapes. Factors which should be incorporated into a regular maintenance schedule are listed below:

1. Fertilizing

Fertilization should be based upon the recommendations of a soils analysis to ensure optimum nutrient levels for healthy plant growth. Be careful not to over fertilize as this will promote very fast growth that will use more water. Plants grown in this way are less able to tolerate drought.

2. Weeding

Regular weeding should be included in your maintenance program. Weeds compete with your landscape plants for water, nutrients, light, and space. In some cases, weeds can harbor insects and diseases. Weeds should be removed promptly to prevent them from spreading throughout your landscape.

3. Pruning

Pruning of trees and shrubs should be carried out to remove dead, injured, or diseased tissues and to develop proper limb and branch structures. Many shrubs can be pruned to form hedges and to control their sizes. Such pruning should be done on a regular basis rather than once every year or two. Heavy pruning (reducing the plant a quarter or a third) can create overly vigorous growth during the growing season, and this will use more water. Heavy pruning also exposes the soil to more light, which can increase moisture evaporation. A regular pruning program will help to ensure that your plants develop into beautiful specimens.

4. Pest and Disease Control

The effects of a drought are more likely to injure plants already stressed by insects or diseases. Consequently, such infestations should be eradicated as soon as possible by professionals who are knowledgeable about plant and insect infestations.

5. Aeration and Dethatching of Turf

Turf should be aerated and dethatched periodically. This increases the soil's permeability, reduces runoff, and promotes root growth.

6. **Watering--When is Enough Enough?**

- a. **Lawns:** Wait to water a lawn until you notice the color has changed from bright green to a dull blue-green. In addition, when walking on the lawn, while looking back, you should see footprints. These are all signs of water stress, indicating it is time to water.
- b. **Trees and Shrubs:** Regular deep watering encourages deep rooting. By doing this, trees and shrubs with deep roots can go longer between watering and should withstand the drought better. Plants with deep roots have a greater soil reservoir of moisture.
Shrubs and Small Trees: A simple test to see if shrubs and small trees need water is to stick a pencil four to six inches into the ground. If the tip is damp or wet, they do not need water. Remember to check several areas in the landscape, as sunny areas will tend to dry out more frequently than shady areas.
Large Trees: Their roots are typically two to four feet deep or more. You can check if the soil is dry at those depths by pushing a 1/4-inch diameter rod into the soil. The rod will slide easily through the wet areas, becoming harder to push in the dry spots. If the soil is dry where the roots are, it is time to irrigate. Check the soil again after you have irrigated to see if you have given the tree enough water. The best way to water trees is with bubblers or drip irrigation. They put out a small amount of water over a longer period of time, allowing for deep water penetration. If you do not have a bubbler or drip system, dig a circular basin (four to six inches deep) around the tree as wide as its drip line. For large trees, construct a circular basin two feet to three feet around the trunk. Fill the basin three times (allowing it to completely dry before refilling.) This should wet the soil to an adequate depth.
- c. **Ground Cover Areas:** You can check these areas using the pencil test.
- d. **General Tip:** Do not over water. Over watering will damage or kill plants. Do not continue to water an area if runoff occurs; instead, water the area several times allowing an hour or so between watering as this gives the water a chance to penetrate into the soil.
- e. **Moisture Sensing Devices:** Adding these to your automatic irrigation system will greatly simplify the task of watering and eliminate the guesswork of when and how much to water.
- f. See Section VII for sources of additional information.

B. IRRIGATION AND MAINTENANCE

On-going Irrigation Maintenance

- a. *Drip irrigation systems:* These systems require regular maintenance to ensure they properly operate. The filters should be removed and cleaned once a month. The emitters should also be checked once a month for plugged emitters. Poor maintenance can lead to clogged emitters and in turn unhealthy plants.
- b. *Bubblers and overhead spray irrigation systems:* These systems are less prone to clogging. Occasionally insects and other debris can find their way into the sprinkler heads, so they should be checked periodically during the growing season to make sure they are operating properly. These also require periodic adjustments to optimize their irrigation coverage. Typically each spray or bubbler head has an adjustment screw to change its coverage pattern. Spray heads should be adjusted to minimize overspray and misting.
- c. Broken equipment should be repaired or replaced as soon as possible. Faulty equipment can waste water.
- d. *Irrigation controller:* The controller's program should be modified as necessary throughout the year to provide adequate irrigation for the landscape plantings.

VI. GLOSSARY OF TERMINOLOGY

Alkaline Soil:

This is a soil with a pH value above eight. Some alkaline soils may also have high levels of salts. Both of these conditions can harm plants. A soils test should be done to determine this. Contact your local nursery—they can provide you with information on how to obtain a soils test.

Basins:

A circular basin four to six inches deep dug under the drip line of a tree. For larger trees, make the basin two feet to three feet around the trunk.

Bubblers:

An irrigation head that slowly bubbles water out at a low gpm. Typical gpm rates for bubblers range from 1/4 gpm to 2 gpm's. Overhead spray heads may have from 1/2 to 10 or more gpm's.

Drip Emitters:

They are usually small irrigation heads. They have water flow rates ranging from 1/4 to 1/2 gallon per hour. These low flow rates are ideally suited for soils with poor permeability.

Drip Line:

Drip line is the area of ground underneath the tree's or shrub's foliage. Generally, most of a tree's major roots are within the zone.

Drought Tolerant:

A plant that can survive long periods of little or no watering.

Ground Cover:

A small, low growing, spreading plant.

GPM:

Gallons per minute. The number of gallons per minute that typically flows out of a pipe, hose or irrigation head.

Head to Head Coverage:

A term used to describe a pattern in which the sprinkler heads are installed in the landscape. This pattern will apply water evenly to all planting areas being irrigated. An irrigation system not designed with head to head coverage will leave parts of the planting area dry.

Examples: The "throw diameter" is how far a sprinkler head sprays water. "Head to head coverage" (spacing of 50 percent of "throw diameter") for a sprinkler which has a 30 feet "diameter throw" will mean spacing it every 15 feet in the landscape. A 30 feet "diameter throw" will mean spacing it every 15 feet in the landscape. A 30 feet "diameter throw" sprinkler has a 15 feet "radius spray pattern." Since most all sprinklers on the market are described by their "radius spray pattern" (instead of their "throw diameter"), their spacing in the landscape (to have head to head coverage) is the same as their "radius of spray" rating. So a 12 feet "radius spray pattern" head is spaced every 12 feet.

Herbaceous Plants:

A non-woody plant that dies back each year and grows back the next growing season. Perennial plants can also be herbaceous.

Irrigation Controller:

An electronic control unit which can be programmed to turn on the remote control valves in the irrigation system (a remote control valve is one which is turned on by an electrical signal from the control; a manual valve requires you to physically turn it on and off). Many new controllers on the market are run by micro-computers and are quite easy to operate.

Irrigation Valve Circuit:

A single grouping of irrigation heads and pipes connected to one valve forms an "irrigation valve circuit." For example, heads watering the lawn will be on one circuit, while the shrub and ground cover heads will be on a different circuit. This way the controller can water each area independently from the other.

Leaching:

Soils with high levels of salts require periodic heavy flooding to leach or flush the salts out of the plant's root zone. (See Salt Intrusion below.)

Low Angle Heads:

Sprinkler heads which throw or spray water at a low angle (usually less than 30 degrees) above the ground. Some heads have a flat spray, which sprays water horizontally across the planting area. Regular sprinkler heads spray water at a 30 degree or more angle above the planting area.

Low Water Using Plants:

Plants which can thrive in the Foster City climate with a minimum amount of additional water beyond what normally is provided by an annual rainfall.

Microclimate:

A modification of the local climate by conditions unique to your site. For example: a small fence in a backyard located in an area subject to ocean winds will reduce the effects of the wind on plants growing there, thus, making it possible to allow plants not tolerant of such ocean winds to grow.

Overhead Spray:

A term used to describe an irrigation system which employs above-ground watering (where the water is sprayed into the air over the planting area). Drip and bubblers are not overhead spray systems.

Perennial Plants:

A non-woody plant that lives for two years or more.

Permeability:

A soil with poor permeability will absorb water very slowly. Soils with high permeability can absorb water faster.

Pop-Up Sprinkler Head:

A sprinkler head that pops up from its housing. These types of heads—though more expensive—should be used in all planting areas adjacent to sidewalks, driveways, and other areas of foot traffic. Pop-ups do not pose a tripping hazard.

Risers:

A sprinkler head mounted on a solid pipe jutting out of the ground. These should be used where tripping hazards do not occur; e.g., against wall, fences, etc.

Runoff:

Water that runs off the soil's surface, thus not reaching the plant's roots.

Salt Intrusion:

This occurs when salts from the subsurface layers of soil are drawn up via capillary action into the higher areas where plant's roots are located. (See "Leaching" above for more information.)

Soil Amendment:

An organic product (sawdust, manure, bark chippings, etc.) mixed into the soil to improve its moisture-holding capacity and permeability.

Soil Polymers:

A man-made, non-toxic material, when added to a soil, will greatly improve its water- and nutrient-holding capacity.

Slopes:

Four to one designates a horizontal to vertical relationship. This means that for every four feet of horizontal length, the soil rises one foot vertically. A two to one slope is steeper than a four to one slope.

Square Head Spacing:

A sprinkler head layout is where the heads are arranged in a square or box-like pattern (when viewed on plan or overhead).

Triangular Head Spacing:

A sprinkler head layout is where the heads are arranged in a triangular pattern (when viewed on plan or overhead).

Throw Diameter:

How far a sprinkler head sprays water. It is measured in feet. (See "Head to Head Coverage" for more information.)

Xeriscape:

Conservation of water through creative landscaping.

VII. SOURCES AND REFERENCES

A. SOURCES

The following list provides sources of additional information regarding many of the topics discussed above:

East Bay Municipal Utility District, Water-Conserving Plants & Landscapes for the Bay Area. Each drought tolerant plant is depicted in full color, making it easy to choose plants. There are also sections including soil amendments, irrigation systems, and lawn substitutes.

Lane Publishing Co., Sunset Western Garden Book. An excellent all-around garden book in designing and maintaining a landscape.

Lane Publishing Co., Sunset Waterwise Gardening. Full tips on watering, planting design, and selecting irrigation systems.

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Lane Publishing Co., Sunset Magazine, July 1988, "Drip." An excellent article on understanding, designing and installation of drip irrigation systems.

Lane Publishing Co., Sunset Magazine, June 1987, "How Much Water Does Your Lawn Really Need?" An informative article on learning how to water your lawn and save water in the process.

Lane Publishing Co., Sunset Magazine, April 1987, "What About Those New Soil Polymers?" On how to choose and use soil polymers to increase your soil's water holding capacity.

Ortho Books, Easy Maintenance Gardening. How to have a beautiful garden with less effort.

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Reprints of the above magazine articles are available from Sunset Magazine, 80 Willow Road, Menlo Park, CA 94025-3691, (415) 321-3600.

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Estero Municipal Improvement District
**CITY OF FOSTER CITY
CHLORAMINE CONVERSION PROJECT**

FINAL
August 2003



**ESTERO MUNICIPAL IMPROVEMENT DISTRICT
CITY OF FOSTER CITY
CHLORAMINE CONVERSION PROJECT**

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EXECUTIVE SUMMARY

INTRODUCTION

This Executive Summary presents an overview of the chloramine conversion study that was conducted for the Estero Municipal Improvement District's (District's) water distribution system. This summary outlines the system's current deficiencies with respect to operation as a chloraminated system, as well as operational and capital improvement recommendations to address these deficiencies. Conceptual-level cost estimates are included for the recommended improvements.

BACKGROUND

The District's distribution system receives water from the San Francisco Public Utilities Commission (SFPUC) aqueduct system from a single turnout. The District distributes the water to meet the various residential, commercial, industrial, irrigation and other water demands. A group of reservoirs (above ground steel tanks) located in the northern portion of the District near the maintenance yards provides water storage for the system. The District currently has three 4-MG reservoirs, and is considering constructing a fourth 8-million gallon (MG) reservoir at the same location.

Historically, the SFPUC water has been treated with chlorine to protect the water from microbial contamination during distribution. Chlorine, however, forms disinfection by-products (DBPs) that are regulated by the Environmental Protection Agency (EPA) and the California Department of Health Services (DHS). One group of DBPs, the trihalomethanes (THMs), has come under increasing scrutiny in recent years and the acceptable regulatory limits have been lowered.

In response to more stringent THM regulation, the SFPUC is changing their residual disinfectant from free chlorine to chloramines, which are a blend of chlorine and ammonia. Chloramines provide reliable disinfection, but form much lower levels of THMs. This conversion will improve the SFPUC's, as well as the District's, ability to meet the more stringent regulations.

However, inappropriate operation of a chloraminated system can lead to nitrification, which is the biological conversion of ammonia into nitrite, then nitrate. Nitrification can lead to loss of the disinfectant residual and subsequent problems, potentially including violations of the Total Coliform Rule and taste and odor problems. There are a number of water quality factors and physical/operational factors that may contribute to nitrification. In most cases, however, keeping the distribution system in clean condition and controlling the water age will minimize the potential for nitrification.

Purpose

The purpose of this study was as follows:

- To assess how the SFPUC's planned conversion to chloramine disinfection will impact water quality in the District's distribution system.
- To recommend operational and capital improvements to the water distribution system to correct any identified deficiencies.

A number of additional tasks were performed outside of the main goals of this project, including a review of operator certification requirements and water quality regulations, as well as development of a Coliform Episode Action Plan.

SUMMARY OF RECOMMENDATIONS

Recommended Operation During the Conversion

Recommendations for operations during the conversion are based on the assumption that the conversion will occur during the winter, as is currently planned by the SFPUC. The recommended actions are designed to minimize mixing of free chlorinated and chloraminated water, which can lead to a loss of residual due to breakpoint chlorination. The recommended actions are as follows (for details, see Section 6.2):

- Flush 3 to 4 hydrants throughout the conversion to aid movement of the chloraminated water through the distribution system and decrease the time required to empty the reservoirs.
- Empty and fill the reservoirs one at a time, always maintaining two full reservoirs to meet system storage requirements.
- Verify that chloraminated water has reached all portion of the system by testing for total chlorine residual at water quality monitoring sites then dead ends.

Reservoir Operation Following the Conversion

Water age analyses were performed using the District's updated computer hydraulic model under winter and summer conditions. In addition, analyses were performed both with and without the proposed fourth reservoir. The following conclusions were made based on the analyses (for details, see Chapters 3 and 4):

- Current operational practices lead to excessive predicted water age in the reservoirs and the distribution system during winter (low demand) conditions.
- A decrease in the maximum amount of water stored in the reservoirs during the winter will enable the District to avoid excessive water age while still maintaining a high level of storage (see recommended operational strategies in Section 4.3).

- Addition of the fourth reservoir would provide the District with valuable increased storage in the summer and is compatible with the maintenance of high water quality (see summary of storage availability in Section 4.4).

System Maintenance

Keeping the distribution system in a clean condition will be critical for maintaining disinfectant residual levels and avoiding nitrification both during and after the chloramine conversion. The main maintenance activities for keeping the distribution system clean are distribution system flushing and reservoir cleaning. Recommended maintenance activities before and after the conversion are outlined in Sections 6.1 and 7.1, respectively. Carollo's recommendations are as follows:

- Continue to conduct an annual system-wide unidirectional flushing program.
- Flush all dead ends twice per year (once as part of the unidirectional flushing program).
- Regions identified to have high water age should be flushed twice per year. Additional flushing should be conducted at these sites as needed, in response to water quality degradation (based on the nitrification monitoring program).
- Reservoirs should be cleaned at 3 to 5 year intervals. New coatings were recently applied to the reservoirs, so cleaning the reservoirs prior to the conversion should not be necessary.

Nitrification Monitoring and Response

A recommended monitoring plan was developed to aid in the early identification of a nitrification episode. The accompanying Nitrification Action Plan includes guidelines for identifying a nitrification episode using monitoring data, as well as appropriate actions to mitigate an identified nitrification episode. Key recommended actions are as follows (for details see Chapter 7):

- Weekly monitoring is recommended at 12 distribution system sites, as well as at each of the reservoirs and the SFPUC turnout. At each site the following parameters should be measured weekly: total chlorine residual, total ammonia, and nitrite. HPC should be monitored under the increased monitoring program only. This monitoring program is in addition to the monitoring program already conducted by the City to meet regulatory requirements.
- A decision tree is provided to aid in interpreting the monitoring data. The decision tree uses Action Levels 1 and 2 for each of the monitored parameters.
- Increased monitoring will be triggered if significant degradation in water quality parameters is observed.

- Further degradation will prompt action, starting with flushing or reservoir turnover. A series of further actions, finally leading to breakpoint chlorination, are recommended if initial actions are unsuccessful at restoring water quality.

System Materials

Carollo does not expect that the District will experience rapidly increased failure rates of distribution system components. There may be a moderately increased rate of degradation of elastomers, but we do not recommend replacement of existing system components at this time. Piping materials should not be affected by the chloramine conversion. The following actions are recommended to address potential materials degradation (for details, see Chapter 5):

- Conduct annual water audits on the system, comparing the volume of water purchased from SFPUC to the volume purchased by EMID customers, to identify water losses due to failed components.
- Maintain an inventory of replacement components that are both NSF-61 approved and chloramine resistant for expedient repair of failed distribution system parts.

SUMMARY OF ESTIMATED COSTS

All cost estimates are planning-level (-30 percent to +50 percent accuracy).

Estimated Capital Improvement Costs

Table ES.1 summarizes the estimated costs for all capital improvements recommended in the Chloramine Conversion Study. Further details of all costs are provided in Section 6.6

Estimated O&M Costs

The estimated annual O&M costs associated with operational changes recommended for the chloraminated system are summarized in Table ES.2. Additional information on how these costs were estimated is provided in Section 7.5.

Table ES.1 Recommended Capital Improvement Projects Chloramine Conversion Study Estero Municipal Improvement District			
Improvement	Project Implementation Cost	Construction Cost	Total Project Cost
A. Complete Prior to Conversion			
Reservoir Sample Taps	\$9,000	\$30,000	\$39,000
Distribution System Sample Taps	\$6,000	\$20,000	\$26,000
Water Quality Monitoring Kit	\$0	\$2,500	\$2,500
Subtotal	\$15,000	\$52,500	\$67,500
B. Include in Next CIP			
Automate Reservoir Controls	\$39,000	\$130,000	\$169,000
Subtotal	\$39,000	\$130,000	\$169,000
C. As Funds are Available			
Reservoir Flow Meter	\$18,000	\$59,000	\$77,000
Chlorine Injectors for Reservoirs	\$4,500	\$15,000	\$19,500
Mobile Chlorination Equipment	\$0	\$80,000	\$80,000
On-line Water Quality Monitors	\$20,000	\$65,000	\$85,000
Subtotal	\$42,500	\$219,000	\$261,500
Total	\$96,500	\$401,500	\$498,000

**Table ES.2 Estimated Additional O&M Costs
Chloramine Conversion Study
Estero Municipal Improvement District**

	Additional Water Volume Used (MG)	Required Labor (hours)	Direct Costs	Total Costs
A. Chloramine Conversion Costs				
Extra staffing	-	176	-	\$10,030
Wasted Water	17.3	-	-	\$24,280
Total	17.3	176	-	\$34,310
B. Existing Costs				
Existing Water Quality Monitoring Program				
Labor	-	220	-	\$12,540
Annual Unidirectional Flushing				
Labor	-	1,600	-	\$91,200
Water Wasted Through Flushing	22.8	-	-	\$32,000
Reservoir Cleaning	-	-	\$6,000	\$6,000
Total	22.8	1,820	\$6,000	\$141,740
C. New Costs				
Nitrification Monitoring				
Labor (8 hours per week)	-	416	-	\$23,710
On-site Testing Reagents	-	-	\$2,920	\$2,920
HPC Tests	-	-	\$1,050	\$1,050
Bi-Annual Flush of Dead Ends				
Labor	-	160	-	\$9,120
Wasted Water	2.3	-	-	\$3,200
Increased Pumping				
Fuel	-	-	\$6,490	\$6,490
Labor	-	455	-	\$25,940
Total	2.3	1,031	\$10,460	\$72,430

INTRODUCTION

San Francisco Public Utilities Commission (SFPUC), the sole supplier of water to the Estero Municipal Improvement District (EMID), is planning to switch the residual disinfectant in their water from free chlorine to chloramines in the fall of 2003. Chloramines, a blend of chlorine and ammonia, provide reliable disinfection while decreasing the formation of regulated disinfection byproducts such as trihalomethanes (THMs), as compared to free chlorine. This report describes activities conducted under the Chloramine Conversion Study, with the purpose of helping EMID prepare for the upcoming chloramine conversion.

The primary concern with the pending chloramine conversion is the potential for nitrification in the distribution system. Nitrification can lead to a rapid depletion of chloramine residuals, which may subsequently lead to bacterial growth in the distribution system, and violations of the Surface Water Treatment Rule (SWTR) and the Total Coliform Rule (TCR). In addition, nitrification may lead to increases in the heterotrophic plate count (HPC).

Nitrification is a two-stage biological process consisting of the oxidation of ammonia to nitrite, followed by the oxidation of nitrite to nitrate. Nitrification is carried out by bacteria growing in the distribution system that use the ammonia as a food source. The probability of a nitrification episode can be increased by both water quality factors and by physical/operational factors. The critical water quality factors include the chlorine to ammonia ratio, chloramine residual, temperature, and pH. Critical physical/operational parameters include water age (residence time) and pipe conditions (sediment, biofilm, tuberculation). In most cases, however, keeping the distribution system in a clean condition and controlling the water age will minimize the potential for nitrification.

1.1 SFPUC'S CONVERSION PLANS

The SFPUC is planning to change their disinfectant residual from free chlorine to chloramines (a combination of chlorine and ammonia) in the Fall of 2003. This change in residual disinfection practice was recommended in a report titled "Hetch Hetchy Water Treatment Project, Chloramine Conceptual Design Report" prepared by the San Francisco Water Team (CDM, AGS, F.E. Jordan), dated March 1999.

Historically, the SFPUC water has been treated with chlorine to inactivate microorganisms that may be in the water. Chlorine, however, forms disinfection byproducts (DBPs) that are regulated by the Environmental Protection Agency (EPA) and the California Department of Health Services (DHS).

One group of DBPs, the trihalomethanes (THMs), has come under increasing scrutiny in recent years. The original maximum contaminant level (MCL) for the total of four regulated THM species (chloroform, bromodichloromethane, dibromochloromethane, and bromoform)

was 100 µg/L (micrograms per liter or parts per billion) under the Total Trihalomethanes Rule of the EPA Safe Drinking Water Act. Compliance under this rule was determined based on a running annual average (RAA) of samples collected quarterly at all distribution system sample sites. Thus, individual sample sites could have an average THM concentration greater than 100 µg/L.

The MCL for THMs was decreased to 80 µg/L in December of 1998 with the promulgation of the Stage 1 Disinfectant/Disinfection By-Products Rule. Compliance is still determined based on an RAA of samples. Compliance monitoring for the rule started in the first quarter of 2003, with compliance determined after four quarters of sampling. This rule also introduced an MCL of 60 µg/L for haloacetic acids (HAAs), another class of disinfection by-products.

The draft version of the Stage 2 Disinfectant/Disinfection By-Products Rule is expected to be released in the summer of 2003. This rule is not expected to change the MCLs for THMs or HAAs. However, compliance will be determined based on a locational running annual average (LRAA), which means that the average level at each individual sampling site must be within the permissible levels. In addition, this rule is expected to require an Initial Distribution System Evaluation (IDSE) during which new sampling sites for compliance monitoring will be selected.

In response to the more stringent THM regulations described above, the SFPUC is changing their residual disinfectant from chlorine to chloramines. Chloramines provide reliable disinfection, but have a much lower tendency to form THMs, as compared to free chlorine. Hence, the switch to chloramines should decrease the concentrations of THMs in the District's distribution system. In addition, the concentrations of THMs will not be expected to vary greatly across the distribution system once the chloramine residual is in use. This conversion will improve the SFPUC's, as well as the District's, ability to meet the more stringent regulations.

SFPUC's chloramination strategy will begin with chlorine feed at Tesla Portal and ammonia feed at the Alameda Siphon; both of these locations are east of and upstream from the San Francisco Bay Division Pipelines that supply water to the District. The SFPUC is intending to use a chlorine to ammonia ($\text{Cl}_2:\text{NH}_3\text{-N}$) ratio of 5:1 and a chloramine residual of 1.5 milligrams per liter (mg/L) (CDM, 1999). The SFPUC water has low organic carbon and, based on bench studies to evaluate chloramine decay rates, it was concluded that it may be feasible to store water for up to 30 days without inducing nitrification.

During and after startup of chloramination, regular water quality monitoring is planned to track water quality as it enters, resides in, and exits the SFPUC reservoirs. Current inlet/outlet sampling results provide only limited information about the water within the reservoirs and tanks. Therefore, SFPUC is considering developing capabilities to sample from within the tanks at various depths and locations. Modifications to reservoirs may include inlet/outlet reconfiguration, or other reconfiguration of piping within the reservoirs.

Additionally, SFPUC is considering ways to clean storage reservoirs prior to start up, and also perform monthly flushing at key locations to reduce the potential for nitrification in the piping system.

1.2 OVERVIEW OF THE EMID DISTRIBUTION SYSTEM

The EMID system serves approximately 35,000 customers with an average daily demand of around 5.76 MGD. The distribution system consists of a single pressure zone. A group of reservoirs (above ground steel tanks) located in the northern portion of the District near the maintenance yards provides water storage for the system. The District currently has three 4-MG reservoirs, and is considering constructing a fourth 8-MG reservoir at the same location. Water is pumped from these reservoirs using a single pump station, consisting of four pumps. The EMID system receives water from the SFPUC at a single turnout in the north-west corner of the District. The water pressure from the turnout is regulated by two pressure reducing valve (PRV) stations, both located relatively close to the turnout.

1.3 PURPOSE

The purpose of this study was as follows:

- To assess how the SFPUC's planned conversion to chloramine disinfection will impact the facilities and water quality in the District's water distribution system.
- To identify and recommend operational improvements to the water distribution system to correct any identified deficiencies.
- To identify deficiencies that cannot be corrected solely through operational changes.

1.4 REPORT ORGANIZATION

The report is organized to allow the reader to follow the development of the chloramine conversion analysis as it was performed under this contract. The information is presented in chapter form as indicated below:

- Chapter 1 – Introduction: Presents information on the SFPUC's conversion plans, a general description of the District's distribution system, and an outline of the organization of the report. It also includes a discussion of the limitations of the study.
- Chapter 2 – Background: Provides information on the potential causes and implications of nitrification. It also outlines operator certification requirements to operate the District's system after the chloramine conversion.
- Chapter 3 – Hydraulic Model Update: Describes the update of the model to reflect changes to the system that have occurred since model development, model improvements to better reflect the actual system, preparation of the model for water age analysis, and model calibration.

- Chapter 4 – Water Age Analysis: Describes the results of water age analysis of the distribution system, including the development of recommended operational changes.
- Chapter 5 – Materials Evaluation: Provides a review of materials used in the District's distribution system and information on the susceptibility of these materials to chloramines. Includes recommendations for materials to be used in the future.
- Chapter 6 – Chloramine Conversion Plan: Provides guidelines for operating the system during the chloramine conversion, including recommendations for the following: water quality monitoring, maintenance activities, and system operations. It also provides recommendations for capital improvements, including consideration of instrumentation for remote water quality monitoring.
- Chapter 7 – Chloraminated System Operation and Monitoring: Provides guidelines for the monitoring, operation, and maintenance of the chloraminated system, including the estimated cost for the recommended monitoring plan. It also includes a Nitrification Action Plan and a Coliform Episode Action Plan.

1.5 STUDY LIMITATIONS

This study is a planning-level study to assist the District in preparing for the SFPUC's pending conversion to a chloramine disinfectant. It is based on District-provided maps, models, reports, operating data, and meter information. With the exception of some field visits to existing facilities, no detailed field investigations were conducted and no water samples were collected or analyzed. Capital costs presented herein are planning-level estimates suitable for budgeting purposes only.

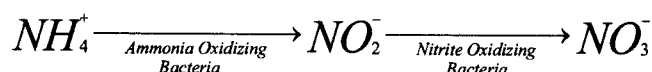
This study is not intended to be a complete analysis of the adequacy of the distribution system for meeting all demand conditions including fire, emergency, or build-out conditions not identified at the time of this report. Rather, the focus of this study was limited to evaluating the water quality and operational impacts of the chloramine conversion. The computer model developed in this study, however, will be a valuable tool for the District to use in evaluating other water demand conditions and operational scenarios to identify other needed improvements.

The purpose of this section is to provide the District with background information on the potential causes and implications of nitrification. In addition, the operator certification requirements to operate the chloraminated system are discussed.

2.1 NITRIFICATION

The primary concern with the pending chloramine conversion is the potential for nitrification in the distribution system. A secondary concern, the potential for increased distribution system component failure, is discussed in Chapter 5.

Nitrification occurs as the result of the activity of slow-growing ammonia oxidizing bacteria (AOB) that nitrify ammonia to nitrite. The ammonia may be naturally present in the water, or may be present due to degradation of chloramine residuals. Subsequent activity by other groups of bacteria can further oxidize the nitrite to nitrate. These bacteria use ammonia and nitrite as an energy (food) source. The overall equation is as follows:



The nitrite produced by the AOB can react with chloramine, further degrading disinfectant residuals and releasing additional ammonia. The loss of the disinfectant residual also contributes to the nitrification potential by no longer inhibiting growth of AOB. Once initiated, nitrification is self-propagating and it may be difficult to stop. Thus, it is desirable to either prevent nitrification episodes, or alternately detect episodes early on before they have gathered momentum.

Understanding where and how nitrification occurs is vital for proper management of a chloraminated distribution system. Negative impacts of nitrification potentially include the following:

- Large increases in numbers of heterotrophic bacteria – May lead to further degradation of the disinfectant residual and taste and odor complaints. The growth of heterotrophic bacteria may also create an environment more conducive to the survival and proliferation of pathogenic bacteria within the distribution system.
- Coliform bacteria occurrences – May lead to violation of the Total Coliform Rule (see Section 2.2.1 below). In addition, some coliform bacteria are human pathogens and may present a public health risk (see Section 2.3 below).
- Increases in nitrite and nitrate concentrations – Nitrite is a particular concern, because nitrite reacts with chloramine to further degrade the disinfectant residual and encourages additional ammonia release, as described above.
- Decreased oxygen levels – Can lead to undesirable taste and odors.

- Decreased alkalinity – Can increase the corrosivity of the water.

2.1.1 Factors That Contribute to Nitrification

Nitrification can be caused both by water quality factors and by physical/operational factors. Water quality factors include chloramine residual, chlorine-to-ammonia-nitrogen ratio, ammonia concentration, temperature, pH, and concentrations of organic compounds. Physical factors include water age (residence time in system), reservoir design and operation, pipe conditions (sediment, biofilm, tuberculation), and the absence of sunlight.

Unfortunately, the water industry lacks an accurate method to predict nitrification episodes. However, there are factors generally recognized to increase the probability of nitrification occurrences, as follows:

- High Water Age: High water age can promote nitrification due to degradation of chloramine residuals with release of ammonia, as well as by allowing for growth of slow-growing AOB. High water age may be due to long reservoir detention times. In addition, lack of mixing may lead to dead-zones with water ages greater than the reservoir's mean.
- High Water Temperature: Nitrification is generally associated with water temperatures above 15 degrees C (59 degrees F). Increased temperature facilitates nitrification both by increasing the activity of AOB and by accelerating chloramine degradation, thereby increasing available ammonia. It is important to note that a temperature lower than 15 degrees C will not necessarily preclude nitrification episodes. A Southern California water utility suffered a severe nitrification episode when the water temperature was 13 degrees C (55 degrees F) and research has demonstrated AOB activity at temperatures as low as 6 degrees C.
- High Ammonia Concentrations: Experience from utilities suggests that a free ammonia residual concentration of 0.05 mg/L $\text{NH}_3\text{-N}$ or less helps limit nitrification. At a $\text{Cl}_2\text{:NH}_3\text{-N}$ ratio of 3:1, free ammonia concentrations are approximately four times higher than at a $\text{Cl}_2\text{:NH}_3$ ratio of 5:1. The SFPUC is planning on using a chlorine to ammonia ratio of 5:1.
- Low Disinfectant Residual: Elevated chloramine residual levels (2 to 3 mg/L) discourage nitrification by inhibiting growth of AOB. The SFPUC is planning on using a chloramine concentration of 1.5 mg/L.
- Slightly Alkaline pH: The optimal pH range for AOB bacteria is 7.2 to 8.5. It is important to note that a pH range outside of the optimal range will not necessarily preclude nitrification events (utilities with pH values ranging from 6.5 to 10.0 have experienced nitrification episodes).
- High Total Organic Carbon: Organic compounds can react with chloramine to form organic chloramine, which is a much weaker disinfectant. The SFPUC water is a low-TOC water.

- High Alkalinity: Elevated levels of alkalinity may promote chloramine degradation and lead to nitrification. However, alkalinity buffers the water and prevents changes in pH, which may help maintain chloramine stability.
- Biofilm Growth: Biofilms formed on sediments and fixed surfaces in the reservoirs and the distribution system may harbor AOB and protect them from disinfection, resulting in an increased potential for nitrification.

Understanding these criteria aids us in evaluating the potential for nitrification to occur in the District's distribution system. It is also useful to review the experiences of other utilities that have converted to chloramine disinfection and what their experiences have been. Summaries of the experiences of a number of utilities are included in Appendix A, including the following California utilities: East Bay Municipal Utility District (EBMUD), Metropolitan Water District of Southern California (MWD-SC), and Los Angeles Department of Water and Power (LADWP).

2.2 FEDERAL AND STATE REGULATIONS

The regulatory requirements for the EMID system have been split into two sections. The first section describes water quality regulations pertaining to distribution systems. The second section describes operator certifications required to operate the system with the chloramine residual.

2.2.1 Water Quality Regulations

The majority of water quality regulations are focused on the water quality leaving the treatment plant. However, there are a limited number of regulations that are focused on the water quality throughout the distribution system. Regulatory requirements for THMs and HAAs are summarized above in Section 1.1. The remaining two regulations that directly address distribution system water quality are the Total Coliform Rule (a component of the Safe Drinking Water Act) and the Lead and Copper Rule.

The District currently monitors for the following parameters: temperature, free chlorine residual, coliform, pH, alkalinity, turbidity, color, odor threshold, trihalomethanes (THMs), haloacetic acids (HAAs), and HPC. Temperature and chlorine residuals are measured in the field. SFPUC analyzes samples for THMs, HAAs, and HPC.¹ The remaining parameters are analyzed by Scientific Environmental Laboratories Inc.².

2.2.1.1 Total Coliform Rule

In 1989, the EPA promulgated a revised total coliform rule (TCR). Under the TCR, utilities must collect and analyze monthly samples representative of water quality throughout the distribution system. The minimum number of samples to be collected is based on the

¹ 650-872-5900, contact name is Cindy Wong

² 924 Industrial Ave., Palo Alto CA, 94303, 650-856-6011, contact name is Shui Fong

population served by the utility. EMID provides potable water to a population of approximately 35,000 customers and is therefore required to collect a minimum of 8 samples per week. Currently, the District collects 10 distribution system samples per week.

Each sample must be analyzed for the presence of coliform bacteria using one of four approved analytical methods. In addition, the rule requires that a detectable disinfectant residual be present at all points in the distribution system. Samples with heterotrophic plate count (HPC) concentrations less than 500 CFU/mL (colony forming units per milliliter) are considered to have a detectable disinfectant residual.

If a sample is coliform positive, the utility must take two actions:

- Analyze the sample for the presence of fecal coliform or *E. coli*.
- Collect a set of three "repeat" samples within 24 hours of confirmation of the positive coliform sample. The repeat samples must include a sample collected at the same location in which the original positive sample was collected, and one upstream and one downstream sample located within five service connections of the original sample site.

There are three situations in which a violation of the TCR occurs:

- Total coliforms are detected in greater than five (5.0) percent of all samples collected in a single month (including both routine and repeat samples).
- A repeat sample contains fecal coliform or *E. coli*.
- An original sample contains fecal coliform or *E. coli* and any repeat sample contains total coliform.

Appropriate responses to these violations are outlined in the Coliform Episode Action Plan (Section 7.4). The DHS may also determine that a "Significant Rise in Bacterial Count" has occurred based on coliform data and other information to be provided by the utility. The associated requirements are also outlined in the Coliform Episode Action Plan.

2.2.1.2 Lead and Copper Rule

A modified lead and copper rule was promulgated in December of 1999. The modified rule did not change the Maximum Contaminant Level Goals (0 mg/L lead and 1.3 mg/L copper) nor the action levels (0.015 mg/L lead and 1.3 mg/L copper) established in the 1991 Lead and Copper Rule. Systems are considered to be out of compliance with action levels if more than 10 percent of samples collected during a monitoring period exceed the action levels (i.e., the 90th percentile values must be less than the action levels).

Additional requirements under this rule include demonstration of optimal corrosion control in the distribution system, lead service line replacement, public education, monitoring, analytical methods, reporting and record-keeping, and special primacy considerations. Tap samples are collected regularly at several sites along the distribution system. The District

indicated that they perform testing every 3 years as required by the DHS. The next sample-year will be 2004.

2.2.2 Operator Certification Requirements

Distribution system operator requirements are based on the classification of the distribution system, which is in turn dependent on the size of the utility. The EMID system serves approximately 35,000 people, which is within the classification for D3 systems (10,001 to 50,000 persons). The requirements for a D3 distribution classification system are as follows: the minimum certification of the chief operator is D3, and the minimum certification of a shift operator is D2. Each water system is required to have one chief operator and one designated shift operator. If the operators are not on-site, the operators shall be able to be contacted within one hour. The requirements for the certification of distribution operators are located in the Table 2.1.

2.2.3 Operator Duties

Only certified distribution operators can make decisions on the following operational activities:

- Install, tap, and re-line, disinfect, test, and connect water mains and appurtenances.
- Shutdown, repair, disinfect, and test broken water mains.
- Oversee the flushing, cleaning, and pigging of existing water mains.
- Pull, reset, rehabilitate, disinfect, and test domestic water wells.
- Stand-by emergency response duties for after-hours distribution system operational emergencies.
- Drain, clean, disinfect, and maintain distribution reservoirs.

Either certified distribution operators or treatment operators that have been trained can make decisions addressing the following operational activities:

- Operate pumps and related flow and pressure control and storage facilities manually or by using a system control and data acquisition (SCADA) system.
- Maintain and/or adjust system flow and pressure requirements, control flows to meet consumer demands including fire flow demands and minimum pressure requirements.
- Determine and control proper chemical dosage rates for wellhead disinfections and distribution residual maintenance.
- Investigate water quality problems in the distribution system.

A certified distribution system operator may add chemical disinfectant to the water as long as the disinfectants are not used to meet primary disinfection requirements (i.e., *Giardia* and virus inactivation). The water supplied by the SFPUC already meets the primary disinfection requirements prior to entering the District's system.

Table 2.1 Eligibility Criteria for Distribution System Operators Chloramine Conversion Study Estero Municipal Improvement District						
		D1	D2	D3	D4	D5
Eligibility Criteria for Taking a Distribution Operator Exam	High School Diploma or GED or Completion of "Basic Small Water Systems Operations" course or One year experience at facility using pumps, valves, and storage tanks	X	X	X	X	X
	Completion of one course of specialized training in water supply principles		X	X	X	X
	Completion of two courses of specialized training with at least one in water supply principles			X	X	X
	Completion of three courses of specialized training with at least two courses in water supply principles				X	X
	Completion of four courses of specialized training with at least two courses in water supply principles					X
	Valid operator certificate of previous level or interim certificate of the same level			X	X	X
	Passed examination within three years of submitting application for certification	X	X	X	X	X
Eligibility Criteria for Distribution Operator Certification	Completed years of operator experience at previous grade level, interim operator at same level, temporary operator of same level at facility with classification at previous level			1	1	2
	Additional years working as a distribution system operator (Note 1)	0	0	1	3	3
Certification Renewal every 3 years	Submit an application to renew certification at least 120 days, but no more than 180 days prior to expiration of certificate	X	X	X	X	X
	Continuing Education Hour Requirements (Note 2)	12	16	24	36	36
Notes: (1) A degree at accredited academic institution may be used to fulfill the experience requirement, as follows: <ul style="list-style-type: none"> • Associate degree or certificate in water or wastewater technology fulfill 1 year of exp. • Bachelors degree in engineering or science will fulfill 1.5 years of experience • Masters degree in engineering or science will fulfill 2 years of experience (2) Continuing Education may be accumulated in contact hours (50 minutes of actual training time). Each CEU is equivalent to 10 contact hours. No more than 25 percent of the contact hours may be operator safety.						